MORPHOLOGICAL VARIATION IN THE SPIONID POLYCHAETE *BOCCARDIA PROBOSCIDEA*

DAVID A. PETCH*

Department of Zoology, University of Melbourne, Parkville, Victoria 3052, Australia
**Current address:* Biosis Research Pty Ltd, 322 Bay Street, Port Melbourne, Victoria 3207, Australia

PETCH, D. A., 1995:07:31. Morphological variation in the spionid polychaete *Boccardia proboscidea*. *Proceedings of the Royal Society of Victoria* 107 (1): 25–30. ISSN 0035-9211.

Specimens of the spionid polychaete *Boccardia proboscidea* from throughout its known geographic range were examined and compared. Despite the wide ecological variation between populations of *B. proboscidea*, no variation in adult morphology was found which would allow separation of specimens from temperate waters. Previously described specimens of *B. proboscidea* from arctic and tropical waters were, however, found to be separate.

THE SPIONID POLYCHAETE *Boccardia proboscidea* Hartman, 1940 has been reported from a wide range of habitats over a wide geographic area around the Pacific basin (Blake & Kudenov 1978). The reported distribution of this species extends along the Pacific coast of North America from Panama to the Bering Sea, surrounding the islands of northern Japan, and along the southern coast of Australia.

The ecological range of *B. proboscidea* has also been reported to be wide. This species has been found: burrowing in soft rock (Hartman 1940); living in crevices on an exposed rock platform (Hartman 1940); amongst coralline algae (Woodwick 1963); in the centre of a colony of the tubeworm *Galeolaria caespitosa* Savigny, 1818 (Hutchings & Turvey 1984); on a sandy beach (Fauchald 1977); among barnacles on jetty pilings (Woodwick 1963); on an intertidal mudflat (Woodwick 1963); in seagrass beds (Imajima & Hartman 1964; Hartmann-Schröder 1982); and, in high densities around major sewage outfalls (Poore & Kudenov 1978; Dorsey 1982; Petch 1989).

The ecological requirements of almost all of the Australian populations of *B. proboscidea* appear dissimilar to those of other populations overseas. In south-eastern Australia, almost all *B. proboscidea* have been found in large aggregations adjacent to major sewage outfalls (Petch 1989). Only one large colony of this species, at Elliston in South Australia (Hutchings & Turvey 1984), and a few scattered individuals have been discovered living away from areas of organic enrichment (Petch 1989). This contrasts with the records of *B. proboscidea* from Japan and North America where only one population has been recorded in an area subject to organic enrichment (Dorsey et al. 1981).

Considering the reported large ecological and geographic ranges of this species and its substantial differences in ecological requirements, at least between North America and Australia, some doubt must exist as to whether populations currently referred to as *B. proboscidea* represent more than one species. The purpose of the present study was to determine whether there was any morphological or morphometric evidence to suggest that this is indeed the case.

MATERIALS AND METHODS

The specimens of *Boccardia proboscidea* examined for the present study were collected from throughout the known geographic and ecological ranges of the species. Sources of museum specimens are indicated by the following abbreviations: USNM, Smithsonian Institution, Washington D.C.; AHF, Allan Hancock Foundation, Los Angeles; and ZMH, Zoologisches Museum Hamburg.

Examination of museum specimens was conducted using light microscopy. Additional material was also examined using scanning electron microscopy (SEM). Specimens for the latter were fixed in 4% formaldehyde then transferred to 70% ethanol, dehydrated through an alcohol series, critical-point dried, coated with gold, and examined with a Philips 505 SEM.

Characters previously used to delineate species in *Boccardia* have included the shape of the caruncle, the distribution of branchiae, the number and type of heavy spines on setiger five, the presence of notosetae on setiger one and the shape of the pygidium (Blake & Woodwick 1971). All specimens examined in the current study were very similar when comparisons were made using the above characters. A more detailed examination of the morphometry of *B. proboscidea* was thus undertaken to establish whether other characters

or combinations of characters could be useful in establishing morphological differences to coincide with ecological differences.

Multivariate discriminant analysis using Systat software (Wilkinson 1990) was used to compare all specimens. Several morphometric measurements were made and these were reduced to a series of ratios to simplify the analysis and to accommodate specimen size, particularly the syntypes which were generally larger than most of the other material. No correlation was found between size and any of the character ratios used in the discriminant analysis. The ratios examined were:

1. Width of setiger five vs. length of the caruncle (ABRAT).
2. Width of setiger five vs. number of hooded hooks on setiger seven (AH7RAT).
3. Number of hooded hooks on setiger seven vs. the number of hooded hooks on setiger sixteen (HHRAT).
4. Number of brush-topped setae on setiger five vs. number of hooded hooks on setiger seven (HHBTRAT).

These ratios were selected to give a representation of the morphometry of the anterior end of *Boccardia proboscidea*. Because of the large number of incomplete specimens examined only characters from the anterior portion of the worm were used.

Specimens were allocated to one of five localities in the discriminant analysis. These were: A, temperate waters of North America; B, southern Australia; C, northern Japan; D, Panama; E, Alaska.

Characters requiring examination of complete specimens were treated in separate analyses. These analyses compared only the North American material with the Australian material as the small numbers of complete specimens from other populations precluded their inclusion. Comparisons using analysis of covariance were made between the total number of setigers and the width of setiger five, and the total number of setigers and the number of hooded hooks on setiger seven. A t-test was used to determine whether there was any difference between populations in the proportion of setigers that bore branchiae. For this analysis the proportional data were normalised using an arsine ($\sqrt{p}$) transformation.

Family SPIONIDAE

Boccardia proboscidea Hartman, 1940

non Polydora californica Treadwell 1914: 203.
HOMONYM *Spio californica* (Fewkes 1889).

Boccardia proboscidea Hartman 1940: 382.—1941: 299.—1944: 259.—1961: 28.—1969: 95.—Hartman & Reish 1950: 27.—Berkeley & Berkeley 1950: 51.—1952: 17.—Woodwick 1963: 132.—1977: 347.—Imajima & Hartman 1964: 279.—Fauchald 1977: 47.—Blake & Woodwick 1971: 31.—Blake & Kudenov 1978: 238.

non Boccardia proboscidea Carrasco 1974: 186.—1976: 8 [= *B. tricuspa* (Hartman)].

Material examined. Syntypes: Caspar, California (39° 25'N,123°48'W), coll. O. Hartman, July 1934. USNM 020217, 10 specimens. *Other material:* U.S.A., locality undetermined, holotype of *Polydora californica* Treadwell, AHF 73254, 1 specimen; Alaska, Bering Sea, St Paul Island (57°05'N,170°15'W), in holdfast with *Fabricia sabella*, coll. W. L. Hahn, 11 March 1911, USNM 24105, 1 specimen; British Columbia, Port Albion, coll. E. & C. Berkeley, 21 May 1945, USNM 40865, 2 specimens; Washington, San Juan Island, False Point (48°30'N, 123°05'W), coll. M. Pettibone, 1937, USNM 45195, 1 specimen; San Juan Archipelago, Brown Island (48°30'N,123°05'W), coll. M. Pettibone, Summer 1937, USNM 45196, 1 specimen; Lopez Island, Flat Point (48°30'N,122°48'W), coll. M. Pettibone, 11 August 1935, USNM 45194, 1 specimen; California, Fort Bragg (39°29'N,123°46'W), O. Hartman, July 1934, USNM 39566, 6 specimens; California, Bodega Lagoon (38°19'N,123°05'W), 15 June 1941, AHF 287, 1 specimen; California, Bodega, (38°19'N,123°05'W), A. Saphire, August 1986, two sites; (a), from the rocky intertidal on an exposed ocean beach; 15 specimens and (b), from a soft sediment in a sheltered embayment, 12 specimens; California, west of Muir Creek, coll. E. & C. Berkeley, 22 July 1959, USNM 40866, 19 specimens; California, Fruitvale Bridge, Lake Merritt, San Franscisco Bay (37°53'N,122°17'W), coll. O. Hartman, AHF 1447, 3 specimens; California, San Mateo (37°33'N,122°22'W), coll. L. Oglesby, 17 March 1961, USNM 39637, 5 specimens; California, Moss Beach (37°31'N,122°31'W), coll. O. Hartman, November 1932, AHF 3463, 6 specimens, burrowing in sandstone; California, Moss Landing (36°45'N,112°47'W), coll. D. Petch, 10 October 1986, two sites; (a) from amongst barnacles on a pier piling on exposed ocean beach; 20 specimens and (b) from amongst soft sediments on the high intertidal region of the Elkhorn Slough a sheltered estuary 20 specimens; Long Beach, Mouth of the San Gabriel River (48°30'N, 117°06'W), coll. D. Petch & J. Laughlin, 4 October 1986, 12 specimens, soft sand, high intertidal; California, Laguna Beach (33°32'N,117°45'W), coll. O. Hartman, 11 December 1935, AHF 1448, 6 specimens, north of pier in soft blue shale; California, La Jolla (32°50'N, 117°16'W), coll. Velero expeditions, 28 November 1940, AHF 1597, 2 specimens; Mexico, Rosarito, Baja California (32°20'N,117°04'W), coll. Velero Expeditions, AHF 2238, 1 specimen; Descanso (32°14'N,116°58'W), coll. Velero Expeditions, 6 March 1940, rocky intertidal, AHF 7923, 10 specimens; Ensenada (31°53'N,116°35'W), coll. Dawson & Durham, AHF 1516-46, 1 specimen; Panama, Patilla Beach, 3 specimens, collection details in Fauchald (1977); Japan, Shirikishinai, Hokkaido

27(41°49′N,141°12′W), coll. M. Imajima, USNM 45198, 1 specimen; Hokkaido, Shirikishinai (41°49′N,141°12′W), coll. M. Imajima, February 1955, AHF 11095, 3 specimens; Australia, Victoria, Port Phillip Bay, Werribee Sewage Treatment Farm, Murtcaim Main Drain (38°03′S, 144°31′E), coll. D. Petch, January to December 1984, 10 specimens. Intertidal soft sediment adjacent to a major outfall discharging secondarily-treated sewage effluent; Victoria, Port Phillip Bay, Werribee Sewage Treatment Farm, 145 West Main Drain (38°00′S,144°36′E), coll. J. Kudenov, 25 August 1976, 10 specimens. Port Phillip Bay, Werribee Sewage Treatment Farm, 145 West Main Drain, (38°00′S,144°36′E), coll. D. Petch, January to Deeember 1984, 10 specimens. Intertidal soft sediment adjacent to a major outfall diseharging secondarily-treated sewage effluent; Victoria, Port Phillip Bay, Werribee Sewage Treatment Farm, 15 East Main Drain (37°59′S, 144°40′E), coll. D. Petch, January to Deeember 1984, 10 specimens. Subtidal soft sediment adjacent to major outfall diseharging secondarily-treated sewage effluent; Victoria, Gunnamatta Beach (38°25′S,144°49′E), coll. D. Petch, January to December 1984, intertidal rock platform on exposed ocean beach adjacent to a major outfall discharging secondarily-treated sewage effluent, 10 speeimens; South Australia, Elliston (33°37′S, 134°34′E), coll. D. Petch, 3–5 July 1985, amongst coralline algae on a sandstone rock platform and in colonies of the tube worm *Galeolaria caespitosa* enerusting jetty pilings, 20 specimens; Western Australia, Fremantle (32°07′S,115°44′E), G. Hartmann-Schröder, 27 August 1975. Inside fishing port in sand with algae, ZMH P-17041. 6 specimens.

Colour. In life, pale yellow all over. Branchiae bright red. Pygidium white. Sooty pigment laterally alongside caruncle forming two long black lines. Ciliated areas of palps also black in some specimens. Four eyespots slightly anterior to insertion of palps, in pairs with posterior pair slightly more medial than anterior pair. Small amounts of sooty pigmentation variously on other parts of body. In alcohol, worm pale yellow all over with only sooty pigmentation and eyespots retained.

Measurements. Syntypes range from 86 setigers (0.61 mm wide at the fifth setiger) to 149 setigers (1.23 mm). Other North American material ranged from 29 setigers (0.58 mm) to 153 setigers (1.53 mm). The Australian material extended from 37 setigers (0.78 mm) to 101 setigers (1.43 mm), while that from Japan ranged from 0.77 mm across the fifth setiger to 1.10 mm. The only complete Japanese specimen was one of 60 setigers (0.98 mm). The Panamanian specimens ranged from 0.56 to 0.61 mm across setiger five and the incomplete specimen from St Paul Island, Alaska was 4.24 mm wide at setiger five.

Description. Prostomium rounded to weakly incised on anterior margin, extending posteriorly to the posterior margin of setiger three. A thick band of cilia runs down either side of caruncle (nuchal organ). Prostomial palps short, extending posteriorly to between setigers ten to fourteen. Notosetae present from setiger one, absent from setiger five, all notosetae simple capillary with fine denticulations along one edge. Neurosetae from setiger one, structure as for notosetae. Setiger five heavily modified. Heavy spines of setiger five of two types; (a) simple, falcate, and (b) bristle topped. Always one less falcate spine than the number of bristle topped spines. Small fascicle of capillary setae present ventral to larger spines on setiger five. Bidentate hooded hooks present from setiger seven, Small fascicle of capillary setae ventral to the hooded hooks present on setigers 7, 8, 9, and no others. Hooded hooks accompanied anteriorly and ventrally by small bulbous papillae. Relationship between the number of hooded hooks on setiger seven and the total number of setigers, $y = 0.003x + 2.69$ ($r^2 = 0.56$, Standard Error of Estimate = 0.96) (range = 4 to 10, average number of hooded hooks on setiger 7 = 6.2). Number of hooded hooks decreases from half way along body to only two to three hooks on the most posterior setigers. Branchiae present from setiger two, absent from setiger five and posterior 10% of setigers. Branchiae do not touch across midline. Relationship between total number of setigers and number of setigers with branchiae: $y = 1.08x - 17.4$, $n = 117$, $r^2 = 0.97$, s.e. = 5.65, $p < 0.001$. Pygidium a broad, flat disc of four unequal lobes, dorsal lobes smaller than ventral lobes.

RESULTS

Statistical Analyses. The results of the discriminant analysis are presented in Fig. 1 and Table 1. No discrimination was possible between the Australian (B) or North American populations (A) from temperate waters. The range of A for both factor 1 and factor 2 entirely encompassed the range of populations B, C, and D. Other character combinations were used in the discriminant analysis; however, all gave essentially the same result. The specimen collected from St Paul Island, Alaska (population E) was the only one clearly demonstrated to be different from the other material (Fig. 2).

The specimens from Panama (population D) were not found to be different using the above analysis. However, differences in other taxonomic characters separate these specimens from remaining temperate specimens of *B. proboscidea*. These data were not included in the analysis because they completely dominated the principal factor and thus

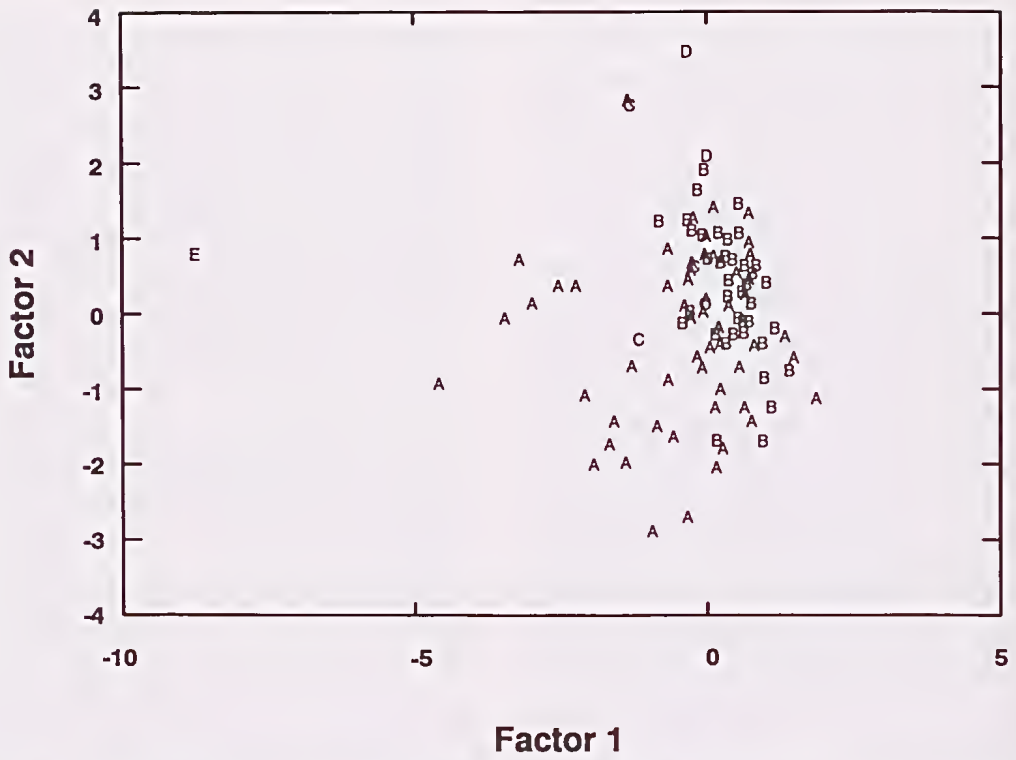

Fig. 1. Distribution of discriminant scores for Factor 1 and Factor 2. Details of the analysis are given in the text. Geographic locations represented are: A, temperate North America; B, Australia; C, Panama; D, Japan; and E, Alaska.

Dependent variable	Factor 1	2	3	4
ABRAT	0.193	−0.179	−0.020	1.013
AH7RAT	−1.585	0.789	−0.996	0.079
HHRAT	−0.387	0.884	0.495	0.151
HHBTRAT	0.738	−1.352	1.292	−0.320
Can. corr.	0.667	0.425	0.249	0.112

Table 1. Dependent variable canonical correlations standardised by conditional (within groups) standard deviations. The definitions of the dependent variables are given in the main text.

obscured any differences between the different temperate populations. The additional characters are the ratio of brush-topped to falcate setae on setiger five, and the distribution of capillary neurosetae along the body of the worm. On the Panamanian specimens the numbers of falcate and brush-topped heavy spines on setiger five are equal, whereas on all other specimens there is invariably one fewer falcate spine than brush-topped spine. The small fascicle of capillary setae that is found only on setigers seven to nine of the temperate water specimens was absent on the Panamanian specimens. On the Alaskan specimen capillary setae were found on all setigers posterior to setiger five.

Analysis of the relationship between the total length of the worm and the width of setiger five revealed no significant difference between the Australian and North American specimens ($F = 1.463$, d.f. $= 1, 76$, $P = 0.230$). Similarly there was no significant difference in the proportion of the body that bore branchiae ($t = 1.88$, d.f. $= 76$, $P = 0.239$) and no difference between the numbers of spines on setiger five and total length ($F = 1.308$, d.f. $= 1, 81$, $P = 0.251$) nor between the number of hooded hooks on setiger seven and total length ($F = 1.279$, d.f. $= 1, 79$, $P = 0.256$).

DISCUSSION

All specimens examined conformed to the original description of *Boccardia proboscidea*. Specimens from Chile described as *B. proboscidea* by Carrasco (1974, 1976) were not examined as Blake & Kudenov (1978) considered Carrasco's reports to refer to *B. tricuspa*. The redescription of *B. proboscidea* divides the specimens examined during this study into three different populations. These are: *B. proboscidea* from temperate waters with a small bundle of capillary setae ventrally on setigers 7, 8, and 9, and ventrally on setiger 5, and with one less falcate seta than brush-topped setae on setiger 5; specimens from Panama with no bundles of capillary setae and a even number of falcate and brush-topped setae on setiger 5; and the single Alaskan specimen with small bundles of capillary setae and an uneven number of heavy spines on setiger 5. The Panamanian material was also distinguished by the ratio of brush-topped spines to heavy spines on setiger five. The Alaskan material was distinguished by the general appearance of the anterior end of the worm (Fig. 1) as well as by the arrangement of the capillary setae. The Alaskan and Panamanian populations probably represent distinct species, but they are not described here due to the poor condition of the material.

The specimens collected from waters between 30° and 50°of latitude exhibited no variation in the adult morphology that would allow distinction between specimens originating from different geographic locations. Despite the collection of specimens from such very different habitats as soft sediments in highly enriched areas surrounding sewage outfalls on sheltered coasts to boring in sandstone on a high-energy surf beach, none of the statistical analyses permitted separation of populations. The choice of characters and statistical techniques used was able to separate *B. proboscidea* from closely related species such as *B. berkelyorum* Blake & Woodwick, 1971 but was unable to detect any inconsistency between populations of *B. proboscidea*.

The results indicate that the adult morphology of *B. proboscidea* from temperate waters surrounding the Pacific basin is remarkably constant. No evidence was found to indicate the presence of more than one species and all adult specimens conform to the type material.

ACKNOWLEDGEMENTS

I am grateful to the following people for their assistance while I was visiting their institutions: Dr G. Hartmann-Schröder and Dr P. Rosenfeldt (ZMH); Dr K. Fauchald (USNM); Ms S. Williams and Ms L. Harris (AHF); Dr K. Woodwick (State University of California, Fresno); Dr J. Nybakken (Moss Landing Marine Laboratory) and Dr R. Smith (Bodega Marine Laboratory). I am also most grateful to Mr Jimmy Laughlin of the Southern California Coastal Water Research Project who provided great assistance during my collecting trip to California and during the subsequent export of specimens to Australia. Dr R. Wilson of the Museum of Victoria read and commented upon drafts of this paper and Dr R. Marchant of the same institution helped with statistical advice. Mr R. Campbell (CSIRO) provided valuable photographic assistance. The work was supported by a University of Melbourne Postgraduate Research Scholarship and a Supplementary Student Grant from the Victorian Institute of Marine Science.

REFERENCES

Blake, J. A. & Kudenov, J. D., 1978. The Spionidae (Polychaeta) from southeastern Australia and adjacent areas with a revision of the genera. *Memoirs of the National Museum of Victoria* 39: 171–280.

Blake, J. A. & Kudenov, J. D., 1981. Larval development, larval nutrition and growth for two *Boccardia* species (Polychaeta: Spionidae) from Victoria, Australia. *Marine Ecology—Progress Series* 6: 175–182.

Blake, J. A. & Woodwick, K. H., 1971. A review of the genus *Boccardia* Carazzi (Polychaeta: Spionidae) with descriptions of two new species. *Bulletin of the Southern California Academy of Science* 70: 31–42.

Carrasco, F. D., 1974. Spionidae (Polychaeta) proventientes de la Bahia de Concepcion y lugares adyacentes. *Bolletin de la Sociedad de biologiá de Concepción* 48: 185–201.

Carrasco, F. D., 1976. Larvas de la familia Spionidae (Polychaeta) en el plancton de la Bahia de Conception, Chile. *Gayana Instituto de Biologia e Zoologia* 38: 1–63.

Dorsey, J. H., 1982. Intertidal community offshore from the Werribee Sewage Treatment Farm: an opportunistic infaunal assemblage. *Australian Journal of Marine and Freshwater Research* 33: 45–54.

Dorsey, J. H., Green, K. D. & Rowe, R. C., 1981. Effects of sewage disposal on the polychaetous annelids at San Clemente Island, California. In *Waste Disposal in the Oceans, Minimising Impact, Maximising Benefits*, D. F. Soule & D. Walsh, eds, Westview Press, Boulder, Colorado, 19–39.

FAUCHALD, K., 1977. Polychaetes from intertidal areas in Panama, with a review of previous shallow-water records. *Smithsonian Contributions to Zoology* 221: 1–81.

HARTMAN, O., 1940. *Boccardia proboscidea*, a new species of spionid worm from California. *Journal of the Washington Academy of Sciences* 30: 382–387.

HARTMANN-SCHRÖDER, G., 1982. Die Polychaeten der subtropisch-antiborealen Westküste Australiens (zwischen Cervantes im Norden und Cape Naturaliste im Süden). *Mitteilungen aus dem Hamburgisches Zoologiches Museum und Institut* 79: 51–118.

HUTCHINGS, P. A. & TURVEY, S. P., 1984. The Spionidae of South Australia (Annelida/Polychaeta). *Transactions of the Royal Society of South Australia* 108: 1–20.

IMAJIMA, M. & HARTMAN, O., 1964. The polychaetous annelids of Japan. 1–11. *Allan Hancock Foundation, Occasional Papers* 26: 1–452.

POORE, G. C. B. & KUDENOV, J. D., 1978. Benthos around an outfall of the Werribee sewage treatment farm. *Australian Journal of Marine and Freshwater Research* 29: 157–167.

PETCH, D. A., 1989. Variation in the Spionid polychaete *Boccardia proboscidea* Hartman 1940. Unpublished Ph.D thesis, University of Melbourne. 136 p.

WILKINSON, L., 1990. *SYSTAT: The System for Statistics*. Systat Inc., Evanston, Illinois, U.S.A. 678 p.

WOODWICK, K. H., 1963. Comparison of *Boccardia columbiana* Berkeley and *Boccardia proboscidea* Hartman (Annelida, Polychaeta). *Bulletin of the Southern California Academy of Sciences* 62: 132–139.